Bull. Environm. Contam. Toxicol. 26, 108-115 (1981)

Effects of Dichlorprop and Mecoprop on Respiration and Transformation of Nitrogen in Two Soils

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MARSH et al. (1977) and DAVIES & MARSH (1977) discussed the concern that herbicides may influence soil microorganisms and thus soil fertility. GREAVES et al. (1980) recommended tests for assessing the side effects of pesticides on the soil microflora. This paper describes some effects of dichlorprop and mecoprop on respiration and nitrogen transformation in two soils, as recommended by these authors.

MATERIALS AND METHODS

Soils used (Table 1) were classified as sandy loams and came from arable (Boddington Barn) and permanent grass (Triangle) fields at the Weed Research Organization. They were collected in October of two successive years.

Herbicides tested were dichlorprop [2-(2,4-dichlorophenoxy) propionic acid K-salt] as an aqueous concentrate containing 500 g a.e. l (Marks Polytox-K) and mecoprop [2-(4-chloro-2-methyl-phenoxy)propionic acid, K-salt], as an aqueous concentrate containing 650 g a.e. l (Marks Mecoprop K). Both were obtained from A.H. Marks & Co Ltd., Bradford, Yorks.

Table 1. Soil characteristics.

Soil	Boddington Barn		Triangle	
Experiment	1	2	1	2
pH (in water)	5.7	6.5	4.8	5.8
Available P, µg P g^{-1} dry soil	10.0	20.7	3.2	2.6
Total N, %	0.17	0.15	0.36	0.36
Organic C, %	1.6	1.4	3.6	3.3
NH_4^+ - N, µg N g^{-1} dry soil	<1	<1	6.1	1.4
NO_3^- - N, µg N g^{-1} dry soil	60.1	11.2	97.1	27.2
CEC, mEq/100 g	24	23	39	44
Clay, %	15	17	17	17
Silt, %	14	14	17	18
Fine sand, %	41	33	34	36
Coarse sand, %	30	36	32	29
Moisture content when collected, % H_2O	10.5	15.5	21.1	26.2
Field capacity, % H_2O	16.6	16.6	27.8	27.8

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Moist soil was treated to give average herbicide concentrations of 10 and 100 ppm active ingredient, calculated on an oven dry basis. These figures are approximately equivalent to field and 10 x field rate distributed evenly in the top 2 cm of soil. Moisture contents of control and treated soils were adjusted to field capacity with deionised water. Methods for the application of the herbicides, incubation and estimation of microbial activity have been described elsewhere (MARSH et al. 1977; GREAVES et al. 1978). A preliminary experiment tested the effects of 100 ppm and a second experiment tested this and a more realistic concentration of 10 ppm. Samples were taken from the dichlorprop-treated soils every 6 weeks and stored at -15°C until analysed for herbicide residues (BYAST et al. 1977). Technical problems prevented analysis of mecoprop-treated soils for residues.

RESULTS

Dichlorprop. In the first experiment, dichlorprop at 100 ppm reduced respiration of Triangle soil, compared to control, for most of the experiment (Fig.1a). In contrast, in Boddington Barn soil CO_2 production was increased during the first 10 weeks (Fig.1a).

In view of the inhibition of respiration noted in Triangle soil, and the possible consequences to soil fertility, a second experiment was set up one year later to test the effects of both 100 ppm dichlorprop and the more realistic 10 ppm. Effects of dichlorprop on respiration were less clear in this experiment. There were only small differences between controls and both soils treated with 10 ppm dichlorprop (Fig.1b). In Triangle soil, unlike the first experiment, 100 ppm caused a slight increase in CO_2 output initially, but subsequently no appreciable differences were observed until after 22 weeks when CO_2 evolution was less in the dichlorprop treatment (Fig. 1b). Also, in contrast to the first experiment in Boddington Barn soil, after an initial stimulation, respiration was reduced for most of the first 14 weeks after application of 100 ppm of the herbicide.

In the first experiment, mineralisation of nitrogen (Fig.2a) in Triangle soil was reduced from week 3 and the herbicide inhibited oxidation of NH_4^+-N to NO_3^--N throughout the test period (Fig.3a) indicating a considerable inhibition of nitrification. In Boddington Barn soil an increase in mineralisation of nitrogen occurred throughout the test (Fig.2a). Data for NH_4^+-N are not given for this soil as only very small amounts were detected in both control and treated soil, and thus the herbicide had not inhibited nitrification. At no time was nitrite detected in either of the experiments.

Key to all figures

Triangle soil: ● , control; ■ , 10 ppm; ▲ , 100 ppm; S.E.1, standard errors.

Boddington Barn soil: ○ , control; □ , 10 ppm; △ , 100 ppm; S.E.2, standard errors.

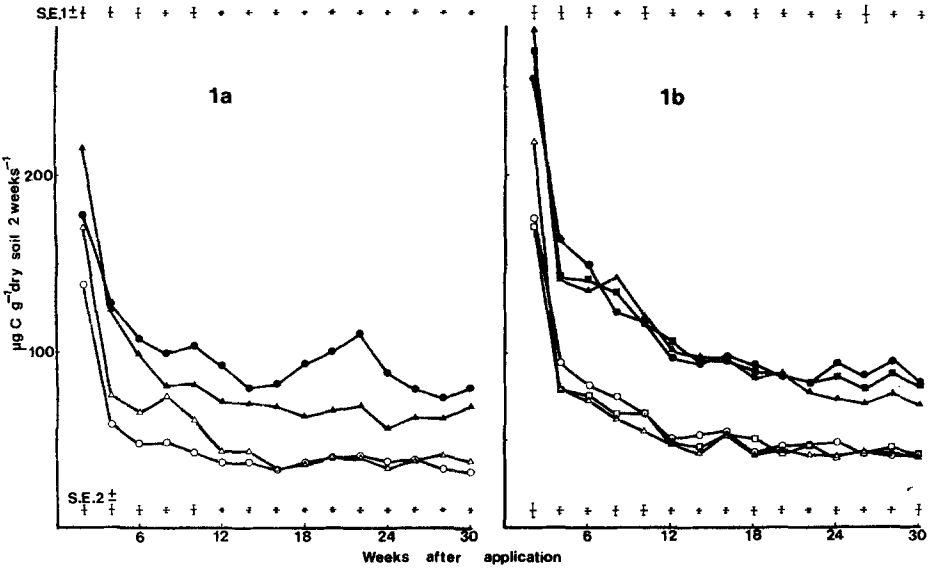

Fig. 1. Effect of dichlorprop on the evolution of CO_2 (each point represents CO_2 accumulated during the preceding 2 weeks).
a) Experiment 1. b) Experiment 2.

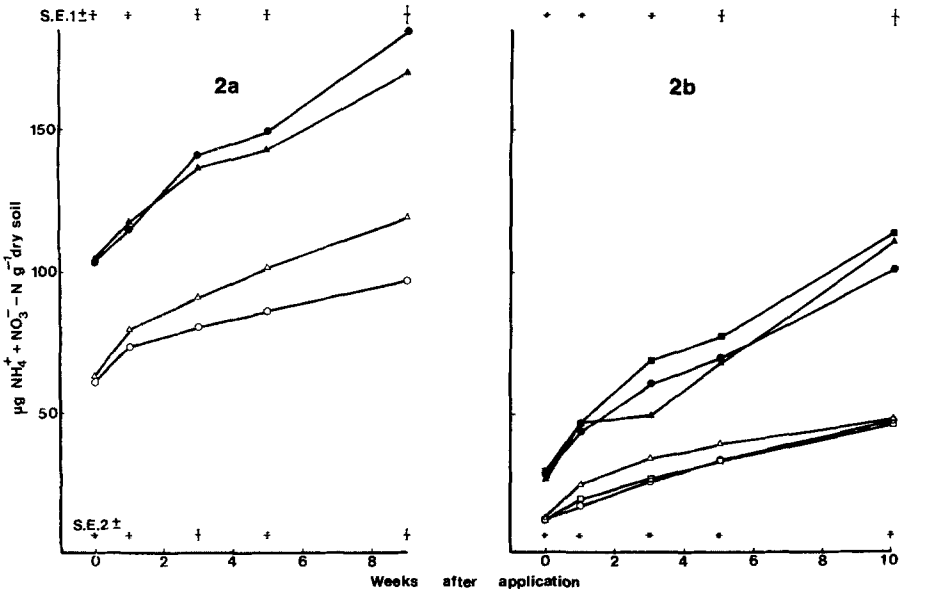

Fig. 2. Effect of dichlorprop on nitrogen mineralisation (continuous aeration after first week of incubation).
a) Experiment 1. b) Experiment 2.

In the second experiment, effects on nitrogen transformation were less marked than in the earlier work. Nitrification in Triangle soil initially was reduced by 100 ppm but by 10 weeks the NH_4^+-N in the soil had returned to control level (Fig.3b). The influence of 100 ppm dichlorprop on mineralisation of nitrogen (Fig.2b) was variable, but at the lower concentration a small, statistically significant, stimulation was observed for most of the test period (Fig.2b). Mineralisation of nitrogen in Boddington Barn soil was temporarily increased by 100 ppm dichlorprop (Fig.2b), but similar amounts of mineral-nitrogen were present in control and treated soils after 10 weeks. Little effect was observed at 10 ppm. Only very small amounts of NH_4^+-N were detected in either control or herbicide treated Boddington Barn soil.

Residue data showed that, in the first experiment, almost 10 ppm dichlorprop was still present in Triangle soil after 30 weeks, but in the second less than 0.5 ppm was detected after 6 weeks. In Boddington Barn soil less than 0.5 ppm was detected after 6 weeks in either experiment.

Mecoprop. In the first experiment, 100 ppm mecoprop initially increased respiration of Triangle soil, but then reduced it throughout the incubation period (Fig.4a). In Boddington Barn soil, respiration was increased for the first 14 weeks (Fig.4a). In the second experiment mecoprop had much less effect. In Triangle soil 100 ppm mecoprop was associated with a large initial increase in CO_2 output (Fig.4b) but results were then variable until a reduction occurred after 22 weeks. Inhibitions of CO_2 output following treatment with 10 ppm occurred at irregular intervals. Respiration of Boddington Barn soil treated with 10 ppm was similar to control soil (Fig.4b) but at 100 ppm CO_2 output was reduced between weeks 4 and 14.

In Triangle soil 100 ppm mecoprop reduced nitrogen mineralisation (Fig.5a) from week 3 and nitrification (Fig.6a) throughout the first experiment, but in Boddington Barn soil no effects on nitrification were observed and mineralisation of nitrogen (Fig. 5a) was increased for most of the 9 week test. No nitrite was detected in either soil in this or the second experiment.

In the second experiment effects of mecoprop on mineralisation of nitrogen (Fig.5b) and nitrification (Fig.6b) were less than in the first experiment. At the lower concentration no effects were observed in either soil. In Triangle soil effects of 100 ppm on mineralisation of nitrogen were variable (Fig.5b). Nitrification was reduced slightly (Fig.6b) but recovered by 10 weeks. In Boddington Barn soil mineralisation of nitrogen was temporarily increased by 100 ppm mecoprop (Fig.5b), but was similar to the control level by 10 weeks. Nitrification in Boddington Barn soil was not affected by the mecoprop treatments.

DISCUSSION

As for other herbicides (TEATER et al. 1958; BARTHA et al.

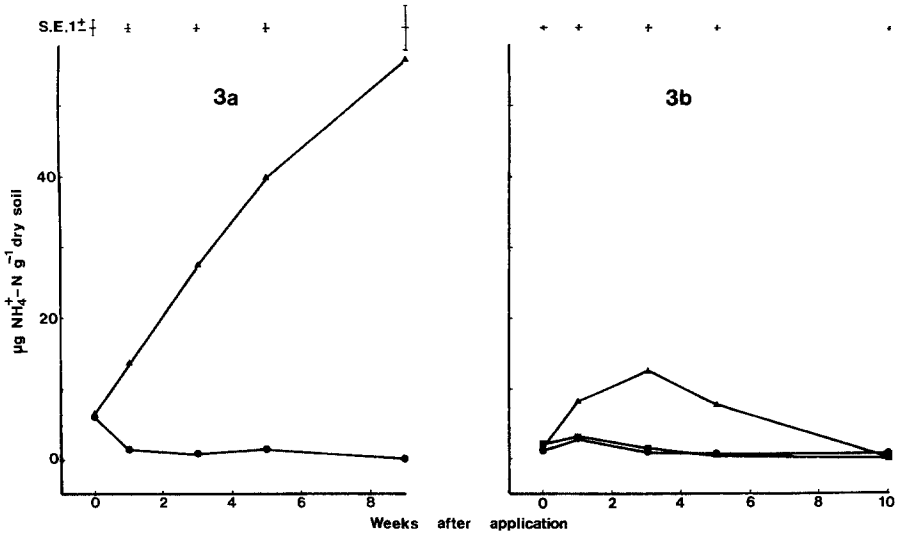

Fig. 3. Effect of dichlorprop on ammonium-N in Triangle soil (continuous aeration after first week of incubation).
a) Experiment 1. b) Experiment 2.

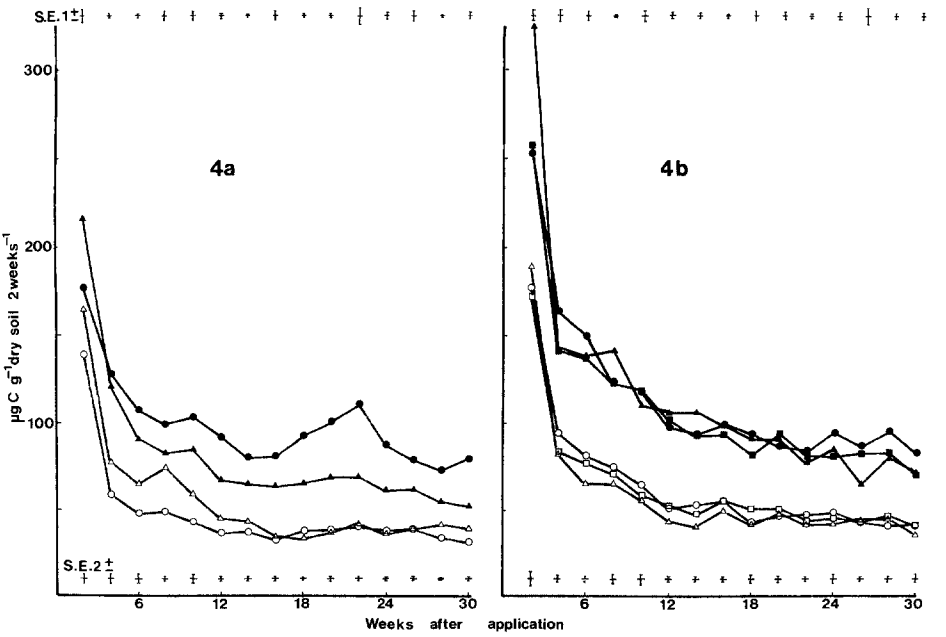

Fig. 4. Effect of mecoprop on the evolution of CO_2 (each point represents CO_2 accumulated during the preceding 2 weeks).
a) Experiment 1. b) Experiment 2.

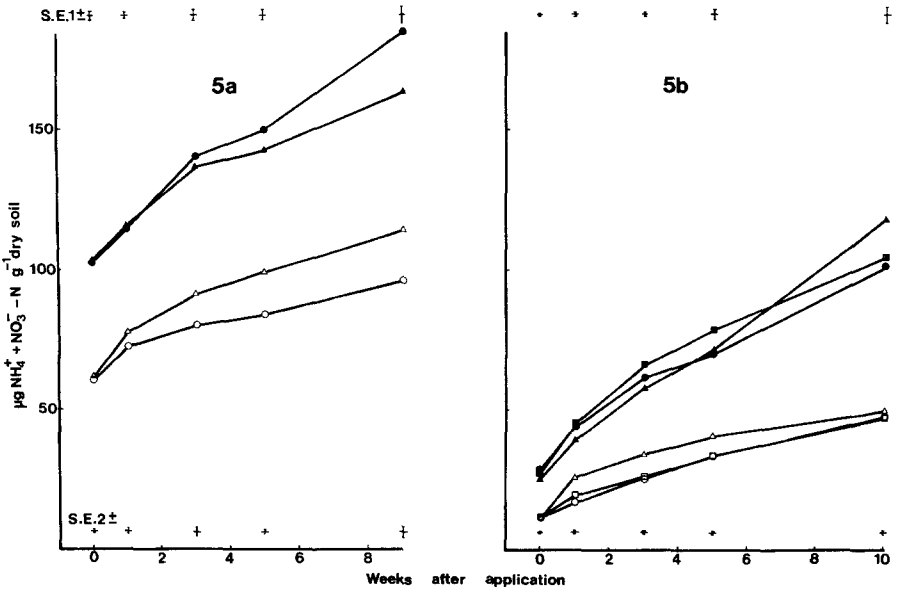

Fig. 5. Effect of mecoprop on nitrogen mineralisation (continuous aeration after first week of incubation).
a) Experiment 1. b) Experiment 2.

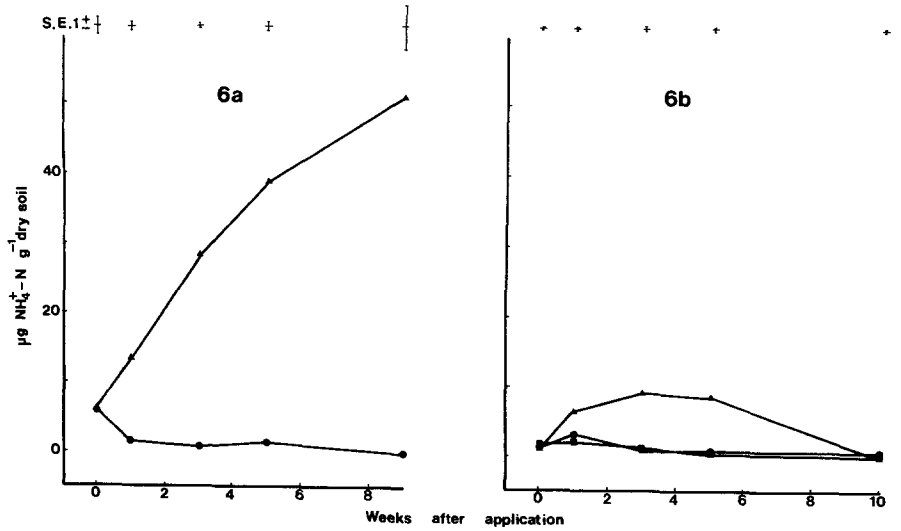

Fig. 6. Effect of mecoprop on ammonium-N in Triangle soil (continuous aeration after first week of incubation).
a) Experiment 1. b) Experiment 2.

1967; GROSSBARD & MARSH 1974; MARSH et al. 1977), both dichlorprop and mecoprop increased CO_2 output during the first 2 weeks after application. MALKOMES (1979) also reported stimulation of respiration after 4 days by dichlorprop in a field experiment. However, VAN SCHREVEN et al.(1970) found that at 10 and 100 times field concentrations dichlorprop and mecoprop significantly reduced CO_2 output from soil during the first week. These authors published weekly and cumulative CO_2 data for 8 weeks and concluded from the cumulative data that the 100-fold rate of mecoprop and both the 10- and 100-fold rates of dichlorprop significantly depress CO_2 production after 8 weeks. However, weekly data for week 8 showed that only with the 100-fold rate of dichlorprop was output significantly different from control. This highlights the dangers of using cumulative data where early transient large effects may mask important changes later.

Both DOMSCH & PAUL (1974) and VAN SCHREVEN et al. (1970) found that, at normal field rates, dichlorprop and mecoprop had little effect on nitrogen mineralisation. However, PASHKIN (1971) observed 20 to 25% increases in nitrate content with normal field rates of mecoprop and VAN SCHREVEN et al. (1970) found that 100 times field rate increased mineralisation of nitrogen for several weeks. This latter result is confirmed by the results for Boddington Barn soil, but results from Triangle soil in the first experiment showed a decrease in mineralisation. In our experiments both dichlorprop and mecoprop reduced nitrification in Triangle soil to a similar extent, but VAN SCHREVEN et al. (1970) found that their highest rate of dichlorprop reduced nitrification for much longer than did mecoprop.

Both dichlorprop and mecoprop produced greater effects in the first experiment. For example after the initial stimulation, both herbicides caused a continuous significant inhibition of CO_2 output from Triangle soil, but when the experiment was repeated this did not recur. These differences may arise from changed circumstances at the time of soil collection. The moisture content and pH of the soils when collected differed greatly in the two years. The soils for the first experiment were collected after dry weather, but soils collected for the later experiment were very wet (Table 1). This may have led to the microflora in the first experiment being more susceptible to herbicides than in the latter. Heavy rain prior to collection of soil for the second experiment would have leached nitrates down the profile, resulting in the low levels of mineral-nitrogen in these soils. The lower pH of the soil in the first experiment, particularly Triangle soil, also may have led to the microorganisms being more sensitive to herbicides (DAVIES & MARSH 1977). These results emphasise the need to test effects of herbicides on soil microorganisms in different soils. They show also that interactions of herbicides and soil microorganisms are markedly affected by changes in environmental conditions and further research is necessary, therefore, before unequivocal interpretation of side effect data can be made.

The non-reproducibility of tests of side-effects of pesticides is a serious problem. Clearly, if the same soil, sampled at different times, gives different results for the same compound, the basis of side-effect testing in laboratory experiments is questionable and care must be taken in interpreting data. Using the approach suggested by DOMSCH (GREAVES et al. 1980), the results of the first experiment could suggest that dichlorprop and mecoprop are harmful. In particular, the prolonged inhibition of respiration could give concern and be classed as "critical" (GREAVES et al. 1980). On the other hand, the largest effect is less than the variation of 50% or more which can occur under natural conditions, and the overall effect may be less than "critical". Certainly, the data from the second experiment suggest that, even at 100 ppm, the herbicides do not cause "critical" effects on respiration. Similarly, the effects on nitrogen mineralisation are not "critical". The prolonged inhibition of nitrification was large, but the accumulation of ammonium-nitrogen may be beneficial to soil fertility as it is not leached from soil. Thus, as total mineralisation is hardly affected, the effect on nitrification can be regarded as "tolerable" if not desirable. This assessment is confirmed in the second experiment where the inhibition was smaller and less persistent.

Acknowledgements. We thank K. Holly and E. Grossbard for advice, B.O. Bartlett and S. Ridge of the Letcombe/WRO Statistics Section for statistical analyses, C.E. McKone and E.G. Cotterill of WRO Chemistry Group for residue analyses, and C.J. Standell for assistance and the manufacturers for supplying the herbicides.

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